EFFECTS OF INTERLIMB TRANSFER IN LEARNING AND RETENTION OF SEQUENCES

By

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Abstract

The current study investigated the effects of interlimb transfer in learning and retention of movement sequences in mirror and non-mirror conditions using a simple four element sequence learning task. A total of Forty eight healthy, Right Handed subjects were recruited for the study. The subjects are required to perform a few key presses following a stimulus on a color monitor using a standard numerical keyboard. Four conditions were tested which include 1) right hand practice with mirror 2)right hand practice with non-mirror, 3) left hand practice with mirror, and 4) left hand practice with non-mirror. The reaction time (RT), movement time (MT), total time (TT), were measured using E-prime software program. Two way ANOVA was conducted to see the main effects and interaction effects of practice, retention and transfer for mirror and non-mirror conditions. The two-way ANOVA conducted on MT measures showed significant interaction effects. The practice Hand x Retention Test indicated for the left mirror condition, practicing with the left hand was significantly slower than practicing with the right hand, whereas for non-mirror retention condition, there is no significant difference in practicing either with the right or left hand. The Retention Test x Practice Hand interaction is also significant, for the left hand practice condition, mirror was slower when compared to non-mirror, whereas for the right hand practice condition, non-mirror was slower compared to mirror. Our results indicate differences in motor code execution while processing mirror vs. non–mirror condition with right and left hands.

Keywords: Sequence Learning, Hemispheric Specialization, Interlimb transfer, Hand Dominance.

CHAPTER I

Introduction

Generally, motor skill acquisition is a continuous process that starts with birth and continues throughout the life; however, irrespective of the ethnicity, gender, and geographic location, majority of the human beings are biased when it comes to the utilization of a specific hand, either right or left more frequently during activities of daily living. The reasons underlying such preferences are beyond the scope of our study. However, considering the fact that during the unforeseen circumstances following a disease and/or injury, one may have to rely on the opposite non-dominant hand to perform activities of daily living. Therefore, learning motor skills with non-dominant hand plays a prominent role during various phases of rehabilitation in the therapy settings.

Motor skill is defined as "ability to achieve an environmental goal with maximum certainty and minimal expenditure of energy and time" (Schmidt & Lee, 1988). Speed and accuracy are equally important and thus any new skill is required to systematically change the speed-accuracy tradeoff (Reis et.al. 2009). Sequence learning is the most common behavior that is associated with learning a new task, for example, while learning a new musical instrument, such as a piano or typing the keys on a computer keyboard, the beginner has to learn the steps and sequence them in an orderly fashion to achieve the desired goal i.e. a specific node on the piano or a word on the computer screen. Once the skill is learned, the learner memorizes the sequences and uses the same to execute whenever required.

Previously, researches questioned whether such learning of sequence saved in the memory as a sensory input or as a motor pattern in the brain for it to be executed when required, For example, Keel et.al (1995) evaluated whether the representation of an action sequence is independent of the effector (motor) system that implements the sequence, and indicated that sequential representation resides in a module prior to the selection of effector systems to execute the movement. Similarly, Cohen et.al (2010) highlighted the role of sensory recall such as compound cuing in association with chunking to recall the skill before execution. Therefore, it is evident that execution of a motor skill is not solely dependent either on the sensory or on the motor framework; however, they mutually contribute to the execution of a task. Another dimension of motor skill acquisition questions whether motor skill learning happens knowingly (explicitly) or unknowingly (implicitly). According to Ghilardi, Moisello, Silvestri, Ghez, & Krakauer (2009), "Learning a sequential motor behavior is comprised of two basic components: explicit identification of the order in which the sequence elements should be performed and implicit acquisition of spatial accuracy for each element." Similarly, Verwey, Groen, & Wright (2015); Willem. Verwey, Shea, & Wright (2015) proposed a cognitive framework for sequential motor behavior following extensive review of various articles based on the assumptions that the movement sequence can either be controlled with a central processor which selects certain movements which are subsequently executed by the motor processor or by the central processor loading a few (4 to 5) movements into motor buffer before they are executed by the motor processor. The article also emphasizes the role of perceptual, central, and motor processors associated with learning and execution of the task. Even though, decoding the exact patterns associated with learning and controlling a motor skill may be difficult considering the flexibility and differences associated with individuals, this paper created a framework based on the previous research to guide the future research on sequence learning. Researchers attempted to generalize the sequence learning with their frameworks; however, they did not account the asymmetries and the hemispheric specializations which are equally important contributors in sequence learning.

Recently, Sahu, Christman, & Propper (2016) studied the contributions of handedness and working memory to episodic memory. Their results indicate significant non-dominant hand advantage to episodic recall, this study also highlighted the need for studies that focus on independent contribution towards hand preference.

Fraser, Li, & Penhune (2009) used a "multifinger sequence task" (serial reaction time task) similar to that of ours but with few differences. They examined within-day and across-day sequence-specific learning in younger and older adults and found that older adults had similar learning patterns to that of younger adults across and within-days. This finding supports our study design that uses learning and retention of a sequence motor skill which can be acquired within a day irrespective of the subject age, It would be interesting to test the role that interlimb transfers play during learning and retention of sequence motor skill.

Robert, McGrath, Shailesh & Kantak (2016) reported that asymmetries were found more in the right-handed compared to left-handed individuals while performing a cursor tracking task. The serial reaction time task emphasizes on the individuals ability to master the speed-accuracy tradeoff with an earlier learned and fixed sequence. Bobrova, Bogachevaa, Lyakhovetskiia, Fabinskajab, & Fominab (2015) studied the positional error and direction of movement errors while right- and left-handed individuals performed the memorized sequence production task with dominant hand and vice versa. This study demonstrated that irrespective of the hand used, more errors were found in the initial repetitions of the sequence and that the proprioceptive target is better learned with the subdominant hand adding up to the previous work highlighting the non-dominant hemisphere's specialized role during proprioception. Additionally, literature on hemispheric specialization during visually guided aiming tasks indicate that left-handed movements are started more quickly (Boulinquez & Bartélémy, 2000), while right-handed movements are completed more quickly once initiated (Elliott et al., 1994). The reaction time to initiate the task which represents the premotor processing time before task initiation may play a role for such differences which can be learned and mastered with practice.

Hikosaka et.al. (1999) proposed a parallel network model in which there are two systems involved during coding of motor skill acquisition, they include visual-spatial coordinates and motor coordinates. The visual-spatial coordinate system is involved during the early phase of learning the code that are represented by the cognitive processor. This provides the motor buffer which is used to form the motor chunks. Once the motor chunks are formed, motor coordinates which come with prolonged practice are triggered by the motor processor and they facilitate movement by combining the chunks which are formed earlier during the visual-spatial coordinates.

Several Neuroimaging studies in the past also showed the primary regions involved during various phases of sequence learning, the primary motor cortex, the supplementary motor area, the basal ganglia, cerebellum and the parietal cortexes (Hikosaka, Nakamura, Sakai, & Nakahara, 2002). Specific brain centers are uniquely active during different phases of learning such as prefrontal cortex, while airing new sequences of motor actions to generate new responses, putamen during sequence learning and retrieval, and cerebellum while the motor task becomes automatic (Jenkins, Brooks, Nixon, Frackowiak, & Passingham, 1994). Similarly, Boyd et.al. (2009) showed structural damage in basal ganglia due to stroke, which results in difficulties to organize movement sequences through sequential chunking.

Mirror writing is “that variety of script which runs in an opposite direction to the normal, the individual letters also being reversed”. Previous research has shown that mirror writing is prevalent among left hand dominant individuals whose literature is read from right to left for example Japanese, Hebrew, and Chinese which may signify implications for hemispheric specialization in relation to handedness Scott (1999) and Schott & Schott (2004). Pathological conditions like vascular disorders that affects the left hemisphere and lesions in the basal ganglia are also associated with mirror writing. The effects of interlimb transfer on the untrained limb were previously studied during tasks such as finger tapping (Laszlo, Baguley, & Bairstow, 1970), pressing a keyboard, inverted and/or reversed writing (Latash, 1999), drawing (Thut et al., 1996), and catching a ball (Morton, Lang, & Bastian, 2001). There is limited research which compares the effects of interlimb transfer between dominant and non-dominant hands. Additional knowledge may provide insight into the role of hemisphere specialization and the possible underlying neural networks that are responsible for such differences if there are any.

CHAPTER II

Statement of Problem

The primary purpose of this study is to investigate the processes underlying learning and retention of sequences and effects of interlimb transfer through the use of interlimb practice paradigm (Panzer et. al, 2011). This study will observe the effects of learning and retention of sequences and specifically interlimb transfer between dominant and non-dominant hand with mirrored and non-mirrored conditions to identify the differences in dwell time.

CHAPTER III

Assumptions

The subjects follow instructions concerning the performance of the task.

The subjects continue to perform the task to the best of their abilities throughout the experiment.

CHAPTER IV

Hypothesis

Hypothesis #1:

Practicing a sequence task with a non-mirror condition would be same as practicing with a mirror condition, irrespective of the hand used, either dominant or non-dominant in right handed subjects.

Hypothesis #2:

Training a sequence task with one limb will not have any facilitating effects on the opposite limb.

CHAPTER V

Research Questions

Does handedness interfere with retention and interlimb transfer?

What are the possible underlying mechanisms associated with facilitation or non-facilitation of such skill in the opposite limb?

Would there be any difference in skill acquisition between mirrored vs. non-mirrored conditions during skill retention and transfer in the dominant and subdominant hands?

CHAPTER VI

Methodology

Participants

Subjects were undergraduate students (N = 48, male = 30, female =18; age (M = 23.96 years, SD = 1.879) at Indiana University who were right-hand dominant as determined by the Edinburgh Handedness Inventory (M =0.86 score, SD =0.138). Subjects with a score of +0.5 are considered right-hand dominant and those with a score less than -0.5 are considered Left-hand dominant. (Oldfield, 1971), all the subjects met the following criteria:

1) No current history of musculoskeletal and/or neural disability and within past months.
2) Conscious, coherent, and alert to verbal commands.
3) Normal or corrected to normal vision.
4) Healthy and young adults.

Apparatus and Task

The testing apparatus consisted of a Pentium-class PC-compatible microcomputer interfaced with a color display monitor and standard keyboard. A customized computer program written with E-Prime v.2.08 controlled all experimental procedures. Stickers placed over the keys of the keypad distinguish the keys that were used during the experiment from those that were not used. During the practice phase of the experiment, participants practiced a four element sequence task which involves pressing a numerical key board following a stimulus that displayed a red screen on the color monitor. The four element sequence key pressing task consists of either 7-6-1-0 or 9-4-3-0 which represented the non-mirror and mirror tasks respectively.

CHAPTER VII

Design

Subjects performed sequence learning experiment using E-prime software. The subject were provided with a computer monitor and a numerical keypad. Prior to beginning the task the subject were given an overview of expectations and the tentative time that were consumed during the task. The subjects were instructed that “the purpose of the experiment is to investigate how fast people can tap out a sequence of keys on a numeric keypad accurately following a stimulus”.

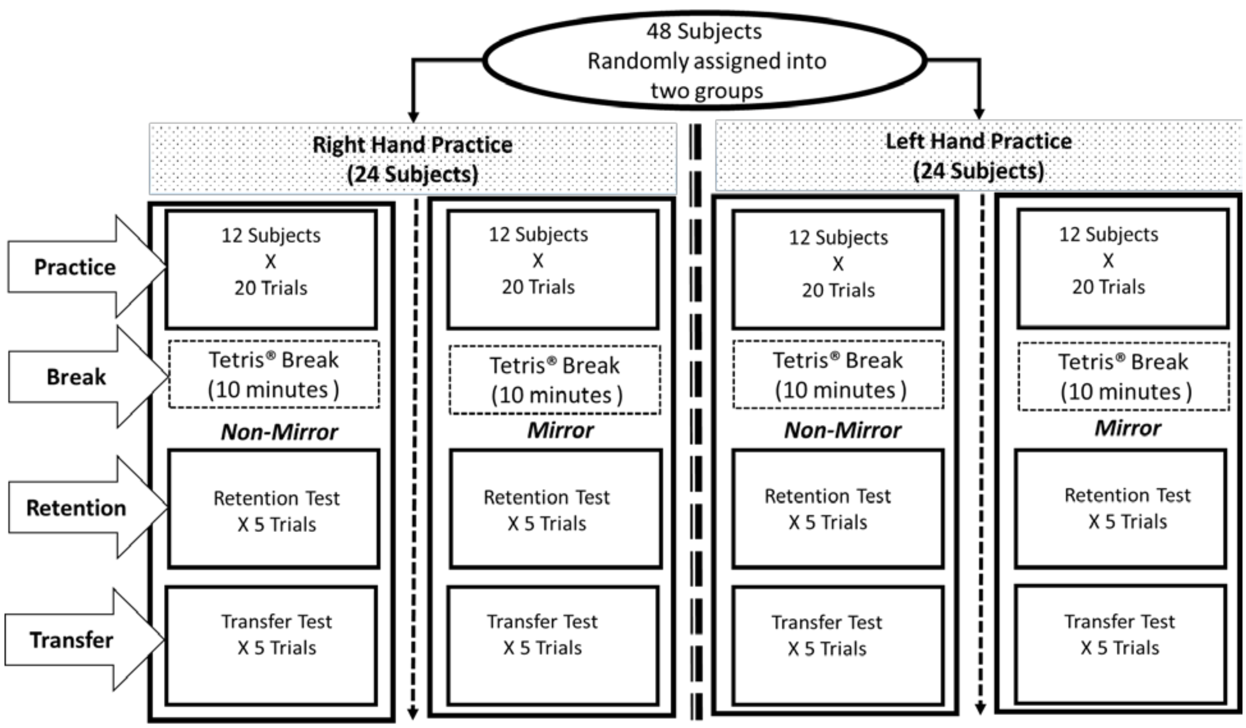

Figure 1 Experiment design layout.

This experiment requires 48 subjects who are randomly assigned to one of the 2 practice groups, the Right Hand practice group and the Left Hand practice group consisting of 24 subjects each respectively. The Right Hand practice group uses the Right index finger whereas the Left Hand practice group uses the Left index finger to learn the key pressing task. The Right Hand practice group and Left Hand practice group groups are further subdivided into two subgroups each. Overall, there were 4 subgroups consisting of 12 subjects each. The experiment consists of three phases. The first phase is practice (Acquisition) phase in which the subjects in both the Right Hand and Left Hand group practiced a key pressing task for 20 trials. The second phase consist of a mandatory break in which the subject plays "Tetris®" game for 10 minutes, and the subjects are instructed to "get the maximum possible score" .The third phase is the retention and test, where the subjects were tested on the retention (retention test) and subsequently the transfer (transfer test) of the skill learned during the practice, using either the dominant hand to the non-dominant hand or vice versa and in either the mirror and non-mirror conditions. Overall, we have four subgroups performing retention test and subsequently transfer test with either mirror to non-mirror conditions respectively, we used reaction time, movement time, and total time to test the difference between interlimb retention and transfer of the learned task between the visual-spatial coordinates (non-mirror) and the motor coordinates (mirror) using the dominant and the non-dominant hands in right handers.

CHAPTER VIII

Procedure

Following an informed consent process, subjects were asked to fill a self-reported, 12 question version of the Edinburgh handedness inventory scale. Subjects' questions were addressed verbally. A "++" in the right hand column indicates strong preference of the task with right hand, and a "+" in the right hand column indicates a normal preference of right hand. Similarly, "++" in the left hand column indicates strong preference with left hand and a "+" indicates normal preference of left hand, for each of the 12 questions in the inventory. A Blank or "0" indicates no experience of the task. The scoring was done as follows: a "++" in the right column is equal to 2 points, a "+" in the right column is equal to 1 point, a blank or a "0" is equal to 0 points, similarly "++" in the left column indicates -2 points, and a + in the left column indicates -1 point. The formula for calculating the handedness is (right-left)/(right + left), The participants whose score of more than 0.5 is considered as right handed and was continued with the next steps in the experiment.

After determining handedness, the subjects were randomly assigned to one of the four subgroups. The four subgroups are as follows: 1) right hand –mirror group, 2) right hand non–mirror group, 3) left hand mirror group, and 4) left hand non–mirror group. The subjects were given a brief overview of the task verbally, and subsequent questions were addressed. The experiment was conducted in a closed room to avoid any audio-visual distractions. The subjects were seated on a wooden chair with no armrest, and the numerical key board was placed securely in the center of the table corresponding to the midline of the subject. Initially, the subjects were directed by the E-prime software program to press and hold a "Start" key until they see a Red color screen on the display monitor. The Red screen acted as a stimulus and the subjects release the "Start" button and perform the task immediately without any delay.

The chronology of events are listed below:

1) A "+" fixation symbol was displayed for about 500 ms.→ 2) A blank screen appears for about 500 ms. → 3) Instruction: either "Use your right hand" or "Use your left hand" appears on the screen depending on the subgroup which was assigned to each subject. →

4) Task diagram appears. 5) A blank screen appears → 6) Instruction: “Press and hold Start Key” → 5) Red Screen (Stimulus)→ 7) Subjects release the start key→ 8) Perform the task. The task involves pressing a four element pattern which involves pressing either 7-6-1-0, or 9-4-3-0 on a standard numerical key board. The stickers placed on the key board did not allow the subjects to memorize the numbers, instead the subject had to follow a sequence pattern as represented on the task diagram at the beginning of every trial. The subjects performed 20 practice trials as part of the practice phase of the experiment. Following practice the subjects were given Tetris break for 10 minutes, and are instructed to play Tetris® game and instructed to score maximum. Following the break, 5 trials of retention test was performed with the same hand and 5 more trials of transfer test were performed with the opposite hand.

CHAPTER IX

Results

For each group tests for acquisition retention and transfer Reaction Time (RT), Movement Time (MT) and Total Time (TT) were recorded in milliseconds (ms). RT was the interval between the onset of the stimulus and the release of the start key. MT was the interval between the onset of the stimulus and the depression of the first key comprising the task. TT was the interval between the release of the first task key and the depression of the last key comprising the task. Trial blocks were used for analyses in acquisition (trial block 1, trials 1-5), (trial block 2, and trials 6-10) (trial block 3, trials 11-15) (trial block 4, trials 16-20). Immediately after the acquisition phase a retention break was provided for 10 minutes in which the participants were instructed to play Tetris® game and to score maximum points. After 10 minutes the participants performed the retention test (trials 21-25), and transfer test (trials 26-30). The total number of errors committed was also recorded for each experimental phase (acquisition, retention, and transfer). Errors were counted when a participant did not hit the correct keys as specified in the task diagram.

A 2 (practice hand: left, right) x 4 (trial block: 1, 2, 3, 4) ANOVA with repeated measures on the last factor was performed on RT, MT and TT measures for Acquisition. A 2 (practice hand: left, right) x 2 (retention condition: mirror, non-mirror) with repeated measures on the last factor was performed on RT, MT, and TT measures for retention test. A 2 (practice hand: left, right) x 2 (transfer condition: right, left) with repeated measures on the last factor was performed on RT, MT, and TT measures for transfer test. In all analyses, the rejection region was $p < .05$. All main effect and interaction post hoc analyses were conducted using a Bonferroni correction for multiple comparisons.

Practice

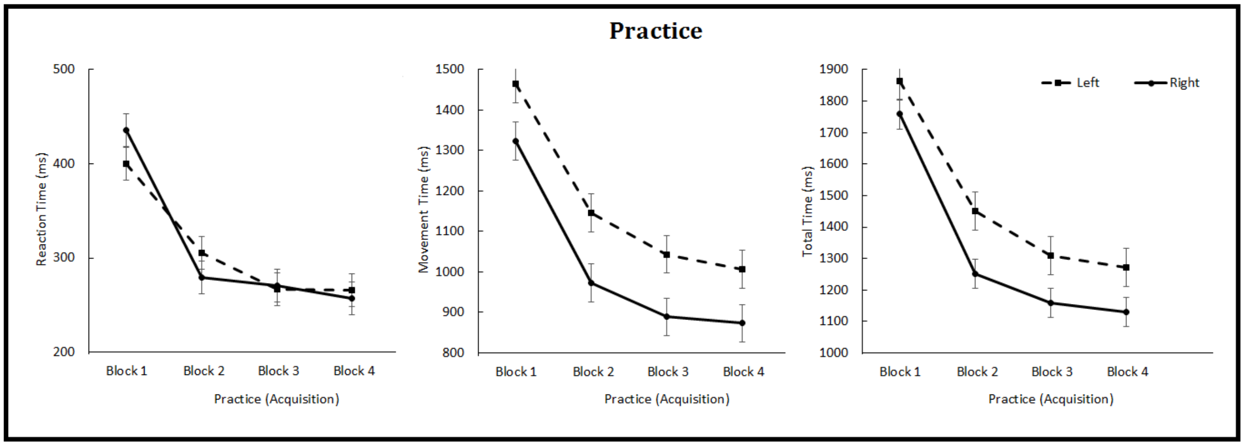

Figure 2. RT, MT, and TT measures for the right and left practice hand groups. Error bars show standard error of mean in milliseconds (ms).

Reaction Time

The two-way ANOVA conducted on RT measures did not show significant main effects for practice hand. However, trial block, F (3,952) = 35.296, $p < .001$, $\eta 2 = .100$, showed significant main effects. Post hoc analyses conducted on main effects showed that the trial block 1 (M = 417.333 ms, SE = 12.248 ms) was slower than trial block 2 (M = 292.117 ms), Trial Block 3 (M = 268.796 ms) and Trial Block 4 (M = 261.554 ms), indicating that the RT practice got more refined as the blocks progressed from the beginning of practice to the end. The Practice hand x Trial Block interaction was not significant.

Movement Time

The two-way ANOVA conducted on MT measures showed significant main effects for Practice hand, F (1,952) = 20.743, $p < .001$, $\eta 2 = .021$, and trial block, F (3,952) = 40.146, $p < .001$, $\eta 2 = .112$ Post hoc analyses conducted on main effects showed that the right hand practice condition (M = 1014.306 ms, SE = 23.31 ms) was faster than the Left hand practice condition (M =1164.475 ms), indicating the right hand advantage over left hand practice. Post hoc analyses conducted on main effects showed that the trial block 1 (M = 1393.200 ms, SE = 32.97 ms) was the slower than trial block 2 (M = 1058.946 ms), trial block 3 (M = 965.750 ms) and trial block 4 (M = 1393.200 ms). The practice hand x trial block interaction was not significant.

Total Time

The two-way ANOVA conducted on TT measures showed significant main effects for practice hand, F (1,952) = 12.243, $p < .001$, $\eta 2 = .013$, and trial block, F (3,952) = 43.789, $p < .001$, $\eta 2 = .121$ Post hoc analyses conducted on main effects showed that the right hand practice condition (M = 1324.902 ms, SE = 30.086 ms) was faster than the left hand practice condition (M = 1473.779 ms). Post hoc analyses conducted on main effects showed that the trial block 1 (M =1810.533 ms, SE = 42.548 ms) was the slower than trial block 2 M = 1351.063 ms, trial block 3 M = 1234.546 ms, and trial block 4 M = 1201.221ms), the practice hand x trial block interaction was not significant.

Retention

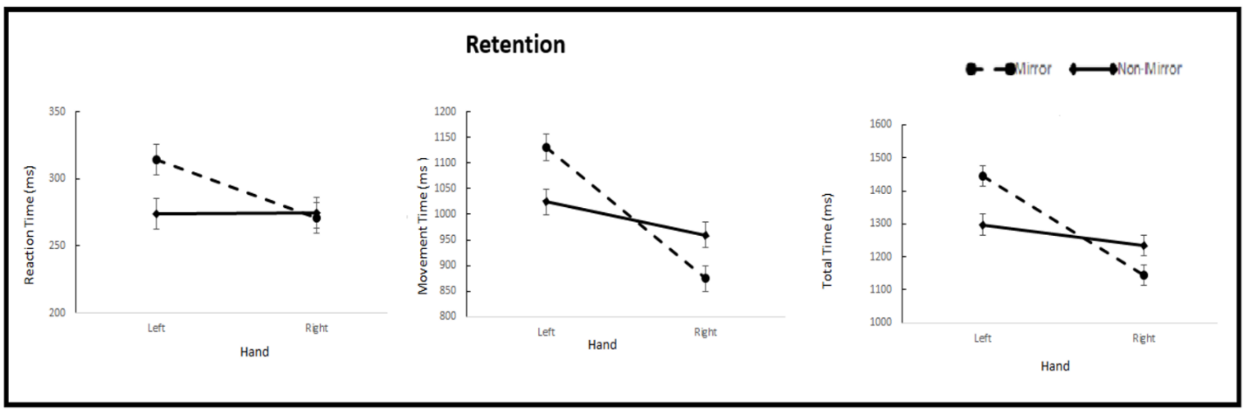

Figure 3. For the retention test RT, MT, and TT measures for the right and left practice hand groups. Error bars show standard error of mean in milliseconds (ms).

Reaction Time

The two-way ANOVA conducted on RT measures did not show significant main effects for neither practice hand (right, left) nor the retention test (mirror, non-mirror). The practice hand x retention test interaction was also not significant.

Movement Time

The two-way ANOVA conducted on MT measures showed significant main effects for practice hand, F (1,236) = 39.491, $p < .001$, $\eta 2 = .143$, Post hoc analyses conducted on main effects showed that the left hand practice condition (M = 1077.350 ms, SE = 18.03 ms) was slower than the right hand practice condition (M =917.108 ms), The practice hand x retention test interaction was also significant F (1,236) = 14.206, $p < .001$, $\eta 2 = .057$. Post hoc analyses conducted on interaction effects showed that for the Left Mirror condition, practicing with the left hand (left hand, M = 1030.650, SE = 25.49) was significantly slower than practicing with the right hand (right hand, M =874.300 ms), whereas for Non-Mirror retention condition, there is no significant difference in practicing either with the right or left hand. The retention test (mirror, non-mirror) x (practice hand: left, right) interaction also showed for the left hand practice condition, Mirror (M=1130.650 ms, SE = 25.49 ms) was slower when compared to Non-Mirror (M=1024.050), whereas for the right hand practice condition, Non-Mirror (M=959.917 ms, SE = 25.49 ms) was slower compared to Mirror (M=874.300 ms).

Total Time:

The two-way ANOVA conducted on TT measures showed significant main effects for practice hand, F (1,236) = 33.223 , $p < .001$, $\eta 2 = .123$, Post hoc analyses conducted on main effects showed that the left hand practice condition (M = 1371.375 ms, SE = 22.265 ms) was significantly slower than the right hand practice condition (M = 1189.883 ms). The practice hand x retention interaction was also significant F (1,236) = 14.086, $p < .001$, $\eta 2 = .056$, Post hoc analyses conducted on interaction effects showed that for left Mirror condition, practicing with left hand (M = 1444.867 ms, SE = 31.488 ms) was significantly slower than the right hand practice condition (M =1145.200 ms), whereas for Non-Mirror retention condition, there is no significant difference in practicing either with right or left hand.

Transfer

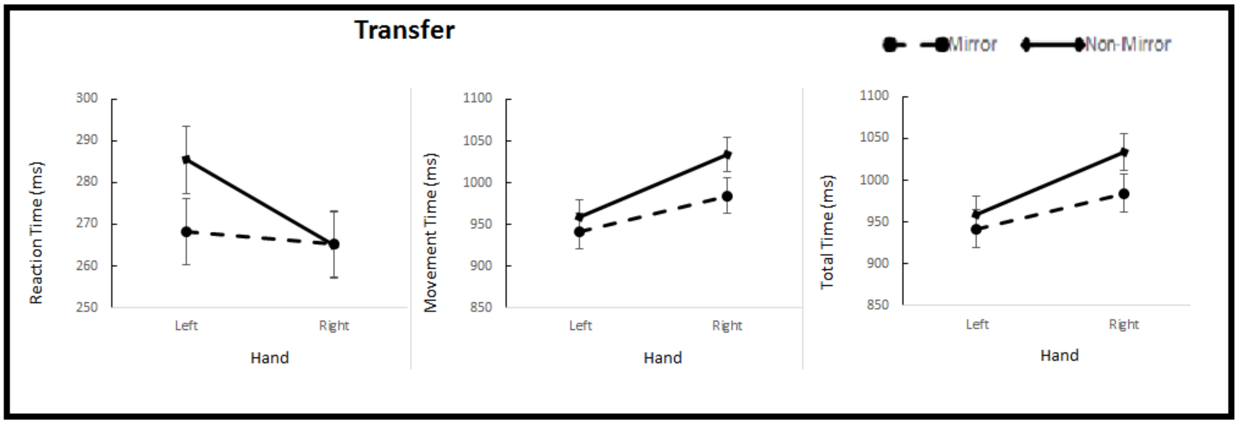

Figure 4. For the transfer test RT, TT, and MT measures for the right and left practice hand groups. Error bars show standard error of mean in milliseconds (ms).

Reaction Time

The two-way ANOVA conducted on RT measures did not show significant main effects for neither practice hand: right, left nor the transfer condition: right, left. The practice hand x transfer interaction was also not significant.

Movement Time

The two-way ANOVA conducted on MT measures showed significant main effects for practice hand, F (1,236) = 7.842, p < .006, $\eta 2$ = .032, Post hoc analyses conducted on main effects showed that the left hand practice condition (M = 950.283 ms, SE = 14.85 ms) was faster than the right hand practice condition (M =1009.125 ms), The main effects of practice hand analysis showed that for transfer test subjects who practiced with right hand showed slower movement time than subjects who practiced with left hand. Even though the interaction between practice hand x transfer is not statistically significant, we can see that for non-mirror condition, subjects practicing with right hand was slower than subjects who practiced with left hand, however for the mirror condition there is no difference between the left and right hand practice.

Total Time:

The two-way ANOVA conducted on RT measures did not show significant main effects for neither practice hand: right, left nor the transfer Condition: left, right). The practice hand x transfer interaction was also not significant.

CHAPTER X

Discussion

The main objective of our research was to study the role that hemispheric specialization plays during the practice (acquisition), retention, and transfer of sequence learning. Specifically, we investigated the role that visual-spatial and motor coordinates play for motor coding in the cerebral cortex. Reaction time, movement time, and total time were used to measure the various stages of motor code execution. Reaction time was the time between the onset of the stimulus and the initiation of the response. Movement time was the time from the initiation of response to the completion of the response, and the Total Time was the time from the onset of the stimulus to the completion of the response. We hypothesized that while acquiring a new sequence task, there would be differences in the right and left hand usage in the right-hand dominant individuals. We anticipated that these behavioral differences may be attributed to the underlying processes associated with movement initiation and execution.

The reaction time we measured was one in which the required response was known ahead by the subjects. The response could therefore be prepared ahead of stimulus presentation and there was no response selection process necessary for performance. However, movement time may reflect specification of the required effectors (muscles and joints), as well as other on-line processing. Finally, total time may represent all the events collectively from stimulus presentation to final task execution. We also hypothesized that there would be significant differences while learning the mirror condition compared to non-mirror condition. This hypothesis was based on previous research pertaining to the specialized role of the subdominant hemisphere pertaining to motor representations compared to the dominant hemisphere pertaining to visual-spatial processing, Goldberg, Podell, & Lovell, (1994).

The most important novel finding in the current study was that during the retention test, movement time showed significant differences between practice with the right and left hand. Movement time for the left hand was significantly slower than for the right hand for the mirror condition. However, there was no significant movement time difference between the right and left hands for the non-mirror condition. We compared the results from the retention test to those of the transfer test to see whether or not the same findings would be found for the opposite hand. Movement time during the transfer test did not show the same pattern of findings as found for the retention test. There was no difference between the right and left hands for the mirror condition, but the right hand was slower than the left hand for the non-mirror condition.

Acquisition

The results in our study show that reaction time differences were not significant different for practice (acquisition), and the retention, and transfer tests. Reaction time was approximately the same for the dominant right hand and the non-dominant left hand. This finding is consistent with previous research (Nisiyama & Ribeiro-do-Valle, 2014). In spite of the structural and functional differences between the right and left hemispheres, the role of the left hemisphere to control the dominant right hand did not show any difference with that of the opposite (non-dominant) hand in this study. There was no significant difference in reaction time between the right (dominant) and left (non-dominant) hands in our study. There is a possibility that the ipsilateral and contralateral connection of the left hemisphere may be the reason for this finding. However, movement time and total time measures, which represent the use of brain's intrinsic or extrinsic coding mechanisms to perform the task, revealed significant differences. The non-dominant left hand performed much slower during the execution of the task. Our findings showed a reduction in reaction time, movement time, and total time across practice trials. Reaction time was significantly slower for the first block of practice trials for the left and right hand practice groups. Movement time and total time for the left and right hand practice groups displayed a near flat line at the end of the last trial block indicating that the learning was successfully achieved. However, there were significant differences in movement time and total time between the right hand practice groups. This difference was probably due to the functional differences between the two brain hemispheres. The right hemisphere is active during execution of contralateral hand movements whereas the left hemisphere is active during both contralateral and ipsilateral movements (Grafton, Hazeltine & Ivry, 2002). It is an undisputed fact that there is no specific area or specific network that is specialized for learning new movement sequences with the right and/or left hands.

Retention Test

The reaction time measure did not show any significant differences between the mirror and non-mirror conditions. The right and left hand practice groups continued to show the same results as those found for the practice condition. This may indicate that for tasks that require short-term memory recall, there is not a significant difference when learning a movement sequence. However, for the retention condition, movement time was significantly slower for the left hand practice group than the right hand practice group for the mirror condition. However, the difference between the left and right hands was not significant for the non-mirror practice group. For the left hand practice group, movement time for the mirror condition was slower than the non-mirror. In contrast, the non-mirror condition was slower than the mirror condition for the right hand practice group. These findings may support the role of interhemispheric connections mediated through corpus callosum. Bonzano (2011) studied patients with mild multiple sclerosis with lesions involving corpus callosum, they demonstrated impairments and a reduced quality of visiomotor learning process with the right hand. While performing a task with the right hand, access to the left frontoparietal connections mediated through the corpus callosum also demonstrate the role of interhemispheric communication while executing a task. Our results may demonstrate yet another layer of connection between the two hemispheres that demonstrate differences while retaining mirror images vs non mirror images.

Transfer Test:

Following practice and retention, our experiment tested the role of transfer in mirror and non-mirror conditions. Our results indicate that right hand practice showed slower movement time than left hand practice for the non-mirror condition. But for the mirror condition, no such difference was found between left and right hand practice conditions. Subjects who practiced with right hand showed slower movement time compared to the left hand. Since this being a transfer test, those who practiced with left hand also transferred to the right hand, and vice versa.

Conclusion

The main objective of our paper is to find out the difference in the motor coding mechanisms while learning a new movement sequence. We tested these differences independently between the dominant and the non-dominant hand in right handers. We hypothesized that there would be differences in the performance of dominant or the non-dominant hands, specifically while execution mirror and non-mirror conditions, our results show that left hand performed better while executing non-mirror condition, whereas the right hand performed better during mirror condition.

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